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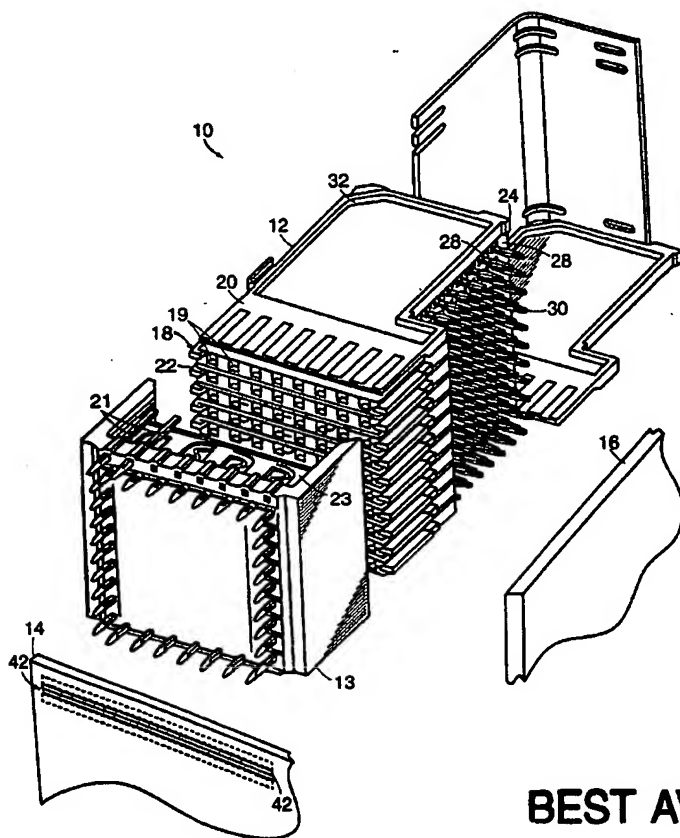
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(54) Title: DIFFERENTIAL SIGNAL ELECTRICAL CONNECTORS



(57) Abstract: An electrical connector for transferring a plurality of differential signals between electrical components (14, 16). The connector is made of modules (18) that have a plurality of pairs (104) of signal conductors (102) with a first signal path and a second signal path. Each signal path has a pair of contact sections (116) extending between the contact portions. For each pair of signal conductors, a first distance between the interim sections is less than a second distance between the pair of signal conductors and any other pair of signal conductors of the plurality. Embodiments are shown that increase routability.

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DIFFERENTIAL SIGNAL ELECTRICAL CONNECTORSRelated Applications

5           This is a continuation-in-part of U.S. Application  
Serial No. 08/797,537, filed February 7, 1997, entitled  
High Speed, High Density Electrical Connector.

Background of the Invention

10           The invention relates to electrical connectors  
and, more particularly, to modular electrical connectors  
that provide signal paths for differential signals  
between mother boards and daughter boards or other  
electrical components.

15           Specialized electrical connectors may be used to  
connect different components of an electrical system.  
Typically, such an electrical connector connects a large  
number of electrical signals between a series of daughter  
boards to a mother board. The mother and daughter boards  
20 are connected at right angles. The electrical connector  
is typically modular. For example, a flat, planar  
metallic lead frame contains several signal paths, each  
of which bends about a right angle within the plane of  
the metallic lead frame. The signal paths are assembled  
25 into an insulated housing that also contains a planar  
ground plate that provides a ground path and provides  
isolation between signals. The module is further  
assembled with other similar modules to form a connector  
capable of connecting a large number of signals between  
30 components in an electrical system.

Typically, the connectors attach to a printed  
circuit board, e.g., a mother board, daughter board, or  
back-plane. Conducting traces in the printed circuit  
board connect to signal pins of the connectors so that  
35 signals may be routed between the connectors and through

the electrical system. Connectors are also used in other configurations, e.g., for interconnecting printed circuit boards, and for connecting cables to printed circuit boards.

5           Electronic systems generally have become more functionally complex. By means of an increased number of circuits in the same space, which also operate at increased frequencies. The systems handle more data and require electrical connectors that are electrically  
10 capable of carrying these electrical signals. As signal frequencies increase there is a greater possibility of electrical noise being generated by the connector in forms such as reflections, cross-talk and electromagnetic radiation. Therefore, the electrical connectors are  
15 designed to control cross-talk between different signal paths, and to control the characteristic impedance of each signal path. In order to reduce signal reflections in a typical module, the characteristic impedance of a signal path is generally determined by the distance  
20 between the signal conductor for this path and associated ground conductors, as well as both the cross-sectional dimensions of the signal conductor and the effective dielectric constant of the insulating materials located between these signal and ground conductors.

25           Cross-talk between distinct signal paths can be controlled by arranging the various signal paths so that they are spaced further from each other and nearer to a shield plate, which is generally the ground plate. Thus, the different signal paths tend to electromagnetically  
30 couple more to the ground conductor path, and less with each other. For a given level of cross-talk, the signal paths can be placed closer together when sufficient electromagnetic coupling to the ground conductors is

maintained.

An early use of shielding is shown in Japanese patent disclosure 49-6543 by Fujitsu, Ltd. dated February 15, 1974. U.S. patents 4,632,476 and 4,806,107 (both  
5 assigned to AT&T Bell Laboratories) show connector designs in which shields are used between columns of signal contacts. These patents describe connectors in which the shields run parallel to the signal contacts through both the daughter board and the back-plane  
10 connectors. U.S. Patents 5,429,520, 5,429,521, 5,433,617, and 5,433,618 (all assigned to Framatome Connectors International) show a similar arrangement.

Another modular connector system is shown in US Patents 5,066,236 and 5,496,183 (both assigned to AMP,  
15 Inc.), which describe electrical modules having a single column of signal contacts and signal paths arranged in a single plane that parallels the ground plate. In contrast, U.S. Patent 5,795,191, which is incorporated herein by reference, describes an electrical module  
20 having electrical signal paths arranged in two parallel planes that each couple to a different ground plate.

It appears that the foregoing electrical connectors are designed primarily with regard to single-ended signals. A single-ended signal is carried on a  
25 single signal-conducting path, with the voltage relative to a common ground reference set of conductors being the signal. For this reason, single-ended signal paths are very sensitive to any common-mode noise present on the common reference conductors. We have recognized that  
30 this presents a significant limitation on single-ended signal use for systems with growing numbers of higher frequency signal paths.

Further, existing high frequency high density

connectors often require patterns and sizes of holes in the attached printed wiring boards (PWB) that limit the width and number of printed circuit signal traces that may be routed through the connector footprint portion of  
5 the PWB(s).

We have recognized that, predominantly in a printed circuit backplane, it is highly desirable to have the ability to route on each signal layer multiple traces in various directions between particular patterns, rows,  
10 or columns of holes in the connector footprint. We have also recognized that in higher frequency backplane applications, especially for long path lengths, the ability to route wider traces can be used to reduce conductor losses.

15 We have also recognized that better control of cross-talk can be obtained by designing connectors for differential signals. Differential signals are signals represented by a pair of conducting paths, called a "differential pair". The voltage difference between the  
20 conductive paths represents the signal.

Differential pairs are known in such applications as telephone wires and on some high speed printed circuit boards. In general, the two conducting paths of a differential pair are arranged to run near each other.  
25 If any other source of electrical noise is electromagnetically coupled to the differential pair, the effect on each conducting path of the pair should be similar. Because the signal on the differential pair is treated as the difference between the voltages on the two  
30 conducting paths, a common noise voltage that is coupled to both conducting paths in the differential pair does not affect the signal. This renders a differential pair less sensitive to cross-talk noise, as compared with a

single-ended signal path. We have invented an electrical connector well suited for carrying differential pairs.

In addition, it is advantageous to have symmetrical, balanced electrical characteristics for the two conductive paths of a differential pair. Because current connectors have signal paths of different lengths (as shown in FIGS. 2 and 3), the electrical delay of each path is not equal, which can degrade the differential signal quality by inducing skew. It would be highly desirable to have a differential connector that has balanced paths.

Further, it would be desirable to have a differential connector module that is compatible with existing modular connector components. It would also be desirable to have a connector with a circuit board hole pattern that supports multiple wide signal traces and improved routability.

#### Summary of the Invention

One aspect of the invention is an electrical connector module for transferring a plurality of differential signals between electrical components. The module has a plurality of pairs of signal conductors with a first signal path and a second signal path. Each signal path has a contact portion at each end of the signal path, and an interim section extending between the contact portions. For each pair of signal conductors, a first distance between the interim sections is less than a second distance between the pair of signal conductors and any other pair of signal conductors of the plurality.

Another aspect of the invention is an electrical connector module for conducting differential signals between electrical components, the connector module having opposing sides terminating along an edge. The

module contains a pair of signal conductors optimized for coupling to the differential signal. The conductors are disposed in the module. Each one of the conductors has a contact portion that is laterally spaced along the edge  
5 of the module. Surface portions of the pair of conductors pass from the contact portions through the module in a substantially overlaying relationship along a direction extending through the sides of the module.

Each embodiment of the invention may contain one  
10 or more of the following advantages. The impedance of each differential signal path is matched. Each signal path of the pair of differential signal conductors is of equal electrical length. The pairs of differential signal paths can be spaced closer together. The spacing  
15 of each pair of differential signal conductors from other pairs reduces cross-talk within the connector. The pair of differential signal conductors can couple to the ground plate to allow other pairs of differential signal conductors to be placed closer to the signal paths  
20 without inducing cross-talk. A portion of the shield plate can extend between each of the pairs of differential signal conductors. Noise within each pair of differential signal conductors is reduced. The routing of signal traces is efficient. The grounding  
25 contact portions can extend between the contact portions of the signal conductors and allow the signal traces to extend in a direct path through a routing channel. The routing channel can be wide and straight.

30                    Brief Description of the Drawings

FIG. 1 is a perspective view of a system according to the invention wherein a set of modular connectors are assembled between a mother board and a daughter board;

FIG. 2 is a schematic view of a prior art signal path metal lead frame that can be used in the assembly of a modular electrical connector wherein the signal paths are equally spaced and are not arranged in differential pairs;

FIG. 3 is a schematic view of a signal path metal lead frame that is used in the construction of a modular connector wherein the signal paths are arranged in pairs of differential signal conductors in a single plane;

FIG. 4 is a schematic view of still another embodiment of a signal path metal lead frame that is used in the construction of a modular connector wherein the signal paths are arranged in pairs of differential signal conductors in a single plane;

FIG. 5 is a perspective view of a ground plate compatible for use with the signal path metal lead frame of FIG. 4, wherein contact portions of the ground plate are extendable between contact portions of the signal path metal lead frame;

FIG. 5A is a perspective view of a pin header incorporating the ground plate of FIG. 5;

FIG. 6 is a perspective view of an arrangement of signal paths according to the prior art wherein the signal paths are arranged in two parallel planes, each signal path in one plane inductively coupling with a first ground plate (not shown) and each signal path in the other plane coupling with a second ground plate (not shown);

FIG. 7 is a perspective view of another embodiment of signal paths arranged in pair of differential signal conductors, wherein the signal paths are arranged in two parallel planes;

FIG. 8 is a front view of yet another embodiment

of signal paths arranged as a pair of differential signal conductors, wherein the signal paths are arranged in two parallel planes;

FIG. 9 is a side view of the signal paths of FIG. 8;  
5 FIG. 10 is a schematic view of connector module with balanced electrical properties;

FIG. 11A is a sketch illustrating a prior art circuit board signal launch; and

FIG. 11B is a sketch illustrating an improved  
10 circuit board signal launch.

#### Description of the Preferred Embodiments

Referring to FIG. 1, an electrical system 10 includes a modular connector 12 that connects a backplane 14 to a daughter board 16. The connector 12 includes a plurality of connector modules 18 capable of connecting a set of electrical signals, either differential signals, non-differential signals, or both types of signals.

For example, if assembled as described below, the  
20 electrical connector module 18 can conduct a pair of differential electrical signals between electrical components of the system 10 such as the mother board 14 and the daughter board 16. Each connector module 18 has opposing sides 20, 22 that are aligned in parallel. The  
25 sides 20, 22 each terminate along an edge 24 of the connector module 18. (As shown, edge 24 is a planar surface section 28. However, other configurations are possible.) A set of connecting pins 28 extend from the edge 24. Shields (not shown) may be placed between  
30 modules 18.

It should be noted that in a preferred embodiment, the openings 19 in each module 18 are evenly spaced. Likewise, the contact tails 28 are evenly spaced.

Referring to FIG. 2, a metal lead frame 50 defines eight non-differential signal paths 52a-52h for use in connector module 18. The metal lead frame 50 is stamped from a thin, metallic, planar member to include carrier strips 56 that support the signal paths 52a-52h prior to and during assembly of the electrical connector module 18. When the signal paths 52a-52h are fully integrated into the electrical connector module 18, support sections 56 are disconnected from the signal paths 52a-52h, and each signal path 52a-52h is disconnected from the other paths 52a-52h. U.S. Patent Application 08/797,540, High Speed, High Density Electrical Connector, filed February 7, 1997, discloses an electrical connector that incorporates the metal lead frame 50. The application 08/797,540, which is assigned to Teradyne Inc., is incorporated herein by reference.

Referring to FIG. 3, a similar metal lead frame 100, for use in module 18, defines eight signal paths 102a-102h. However, the paths 102a-102h are grouped into four pairs of differential signal conductors 104a-104d. The metal lead frame 100 is stamped with a thin, metallic, planar member that supports the signal paths 102a-102h prior to and during assembly of the electrical connector module 18. When the signal paths 102a-102h are fully integrated into the electrical connector module 18, support sections 106 are disconnected from the signal paths 102a-102h, and each signal path 102a-102h is disconnected from the other signal paths 102a-102h inside the electrical connector module 18.

Each one of the signal paths 102a-102h includes a pair of contact portions 112, 114, and an interim section 116 between the contact portions. The contact portions 112, 114 are connecting pins that connect the module 18

to the electrical components of the system 10. Contact portions 112 are shown as two parallel members. These members can be folded to form a box contact as in the prior art. The box contact acts as a receptacle for a  
5 pin 21 from the backplane. However, separable contact regions of many shapes are known and are not crucial to the invention.

In the present embodiment, the contact portions 112 of the signal paths 102a-102h are laterally and  
10 equidistantly spaced along the edge 118 of the metal lead frame 100. In a preferred embodiment, the spacing is .030". Typically, when attached as part of the system 10, the lateral spacing is in a vertical direction. Both the contact portions 112, 114 extend from the housing 32 of  
15 the module 18. The external structure of module 18 is identical to other modules which are not specifically designed to conduct differential signals. Therefore, the modules 18 are interchangeable with other modules, and the connector 12 can be configured with different types  
20 of modules which allow the connector 18 to conduct both differential and non-differential signals.

The interim sections 116 of each signal path 102a-102h are aligned in a single plane 120, typically a vertical plane. Therefore, surface portions 118 of each  
25 interim section 116 in the pair of conductors 104a-104d are substantially overlaid in the vertical plane.

The each signal path 102a-102h is coupled with a second signal path 102a-102h in pairs of differential signal conductors 104a-104d. For example, signal paths  
30 102a, 102b form the pair of differential signal conductors 104a; the signal paths 102c, 102d form the pair of differential signal conductors 104b; the signal paths 102e, 102f form the pair of differential signal

conductors 104c; the signal paths 102g, 102h form the pair of differential signal conductors 104d. Each signal path 102a-102h of each pair of differential signal conductors 104a-104d is coupled to the corresponding  
5 signal path 102a-102h of the pair 104a-104d. The coupling results because the distance 108 between the pairs of differential signal conductors 104a-104d is small relative to the distance 110 between adjacent pairs of differential signal conductors 104a-104d. The interim  
10 sections 116 of the pairs of signal conductors 104a-104d are arranged as close together as possible while maintaining differential impedance. One of the interim sections 116 of each pair 104a-104d has curved sections 122, 124 that curves toward the other interim section 116  
15 of the pair 104a-104d. Between the curved sections 122, 124, the pair of conductors 104a-104d tracks together along most of the interim sections 116.

The curved sections 122, 124 decrease the distance 108 between interim sections 116 of each pair 104a-104d,  
20 increase the distance 110 between adjacent pairs 104a-104d, and tend to equalize the length of each interim section 116 of the pair 104a-104d. This configuration improves the signal integrity for differential signals and decreases cross-talk between differential pairs 104a-  
25 104d and reduces signal skew.

Other embodiments are within the scope of the invention.

For example, referring to FIG. 4, a metal lead frame 100 includes six rather than eight signal paths  
30 202a-202f. The signal paths are arranged in three pairs 204a-204c. In essence, metal lead frame 200 is identical to metal lead frame 100 except that the equivalent of two signal paths 102c, 102f have been removed. The remaining

traces have to be aligned in pairs as before, with the spacing between the interim sections of the signal paths in a pair less than the spacing between the contact portions. Two spaces 208, 210, which are vacated by the  
5 signal paths 102c, 102f, lie between contact portions 214.

Referring also to FIG. 5, a ground plate 220 contains a main body 230, resilient connecting tabs 224, and contact portions 226, 228. Ground plate 220 is  
10 intended to be used in place of ground plate 23 (FIG.1), particularly in conjunction with the embodiment of FIG. 4.

When a connector 12 is fully assembled and mated with connector 13, the ground plate 222 is parallel to  
15 the signal paths 202a-202f. The contact portions 226, 288 are aligned with the contact portions 212 of the signal paths 202a-202f. The contact portions 226, 228 are each at corresponding right angles to the main body 230 and extend between the contact portions 212 within  
20 corresponding spaces 208, 210.

FIG. 5A shows the backplane module 13' including the shield member 220. There are columns of signal pins 521. Each column contains six signal pins 521, to correspond to the six mating contacts 212. There is no  
25 signal pin in backplane connector 13' corresponding to spaces 208 and 210 (FIG. 4). Rather, contact portions 226 and 228 are inserted into the spaces that correspond to spaces 208 and 210. As a result, there are eight contact tails in each column - six corresponding to  
30 signal pins 521 and two being appending contact tails 226 and 228. The spacing between the contact tails is uniform, illustrated as dimension P in FIG. 5A.

This arrangement of contact tails means that the

spacing between adjacent columns is a dimension D. The spacing D is dictated by the spacing between signal pairs 521 in adjacent columns.

By contrast, in backplane connector 13 (FIG. 1), the space between columns of contact tails for signal pins is occupied by contact tails for a shield plate.

When a backplane connector is attached to backplane, a hole must be made for each contact tail. No signal traces can be routed in the backplane near holes. Thus, to space signal traces across a backplane, the traces generally run in the spaces between columns of contact tails. In the embodiment of FIG. 5A, the spacing D represents a wide routing channel for signal traces. Thus, the signal traces can be made wider and therefore have lower loss. The traces can also be made straighter because they do not have to jog around ground holes in the channels between signal contact tails. Straighter traces result in fewer impedance discontinuities, which are undesirable because they create reflections. This feature is particularly beneficial in a system carrying high frequency signals. Alternatively more traces could be routed in each layer, thereby reducing the number of layers and saving cost.

Referring to FIG. 6, a set of prior art signal paths 300a-300h for use in a modular electrical connector have interim sections 302 that are aligned along two different parallel planes 320, 322. Half of the interim sections are aligned along each corresponding plane. Contact portions 314 are aligned in a third central plane. Contact portions 312 lie in separate planes and are aligned with the third central plane. Thus, when fully assembled, each interim section 302 lies closer to a ground plate than to another of signal paths 300a-300h.

Referring also to FIG. 7, the signal paths of FIG. 6 are adapted to provide a set of differential signal conductors 304a-304d. Each conductor of the pairs 304a-304d includes a pair of contact portions 332, 334 and interim sections 336, 337 extending between contact portions 332, 334. Each pair of interim sections 336, 337 has a corresponding surface 338, 339 that overlays the other corresponding surface 338, 339. The surfaces 338, 339 overlay each other in a direction that extends through the sides 326, 328 of an electrical connection module 303, shown in FIG. 6. Thus, relative to the pairs 104a-104d of FIG. 3 which typically have overlying surfaces 118 in the vertical direction, the pairs 304a-304d typically have overlying surfaces 338, 339 in the horizontal direction. (The comparison between the pairs 104a-104d and the pairs 304a-304d is relative, and the surfaces 338 may overly in directions other than horizontal.)

However, unlike the paths 300a-300h depicted in FIG. 6, interim section 336 of each pair 304a-304d lies closer to corresponding interim section 337 of each pair 304a-304d than to a ground plate or another pair of signal conductors 304a-304d. Therefore, each pair of conductors 304a-304d couples to the corresponding conductor of the pair 304a-304d to reduce noise.

The differential pairs of signal contacts will, preferably be held in an insulative housing, which is not shown. The contacts might be positioned as shown in FIG. 7 and then insulative material could be molded around the interim sections of the contacts. To achieve appropriate positioning of the contact members, a plastic carrier strip might be molded around the contact members in one plane. Then, the contact members in the other plane

might be overlaid on the carrier strip. Then, additional insulative material could be molded over the entire subassembly.

An alternative way to form an insulative housing around the contact members in the configuration shown in FIG. 7 would be to mold the housing in two interlocking pieces. One piece would contain the signal contacts in one plane. The other piece would contain the signal contacts in the other plane. The two pieces would then be snapped together to form a module with the signal contacts positioned as in FIG. 7. This manufacturing technique is illustrated in US patent 5,795,191 (which is hereby incorporated by reference). However, that patent does not recognize the desirability of positioning the interim sections of the signal contacts in the two pieces of the subassembly so that, when the two pieces are assembled, the signal contacts will overlay to create differential pairs.

Referring also to FIGS. 8-9, an alternate arrangement of signal paths includes pairs of signal conductors 304' (here one pair being shown). Like the signal paths 300a-300h of FIG. 6, each conductor 304' of the pair extends toward the corresponding side 326, 328 of a module 303'. However, unlike the signal paths 300a-300h, surfaces 318' of the pair of signal conductors 304' are respectively jogged to have overlaying surfaces 338', 339' in a direction that is perpendicular to the sides 326, 328 of the module 303'. Thus, like the pairs of conductors of FIGS. 3, 4 and 7, the distance between conductors 304' is smaller than the distance from the pair of conductors 304' to other similar pairs of conductors. Also, like the contact portions 312 of FIG. 6, the contact portions 312', 314' all lie in a third

central plane. In comparison, the contact portions 332 shown in FIG. 7 and contact portions 314 shown in FIG. 6 lie in two distinct planes.

As another alternative, it is not necessary that shield plates be used with the differential connector modules as described above.

FIG. 10 shows an alternative embodiment for a differential connector module 510. As described above, a lead frame containing signal contacts is formed into a module by molding plastic 511 around the interim portions of the lead frame. In the module of FIG. 10, windows 512A, 512B and 512C are left in the plastic above the long lead in each pair. These windows serve to equalize the delay for signals traveling in the leads of each pair. As is known, the speed at which a signal propagates in a conductor is proportional to the dielectric constant of the material surrounding the conductor. Because air has a different dielectric constant than plastic, leaving the windows above the long leads, makes the signals in those leads move faster. As a result, the time for a signal to pass through the long lead and the short lead of the pair can be equalized.

The length of each window 512A...512C depends on the differential length between the long leg and the short leg of the pair. Thus, the size of the window could be different for each pair. Also, it is possible that multiple windows might be included for a pair. Further, it is not necessary that the window be filled with air. The window could be formed with a material having a different dielectric constant than the rest of plastic 511. For example, a plastic with a low dielectric constant could be molded over portions of the long contacts in each pair in the window regions. Then,

a plastic with a higher dielectric constant could be over molded to form the plastic housing 511. Also, it is not necessary that the "window" extend all the way to the surface of the conducting signal contact. The "window" 5 could be partially filled with plastic and partially filled with air, which would still have the effect of lowering the effective dielectric constant of the material above the long leg.

One drawback of placing a window in the dielectric 10 material is that it also changes the impedance of the signal contact in the region below the window. Changes in impedance along a signal conductor are often undesirable because signal reflections occur at the discontinuities. To counter this problem, other 15 adjustments can be made to keep the impedance constant along the length of the signal conductors. One way that the impedance can be kept constant is by changing the width of the signal conductors. In FIG. 10, the signal conductors are shown with a width of  $T_1$  in one region and 20 a broader width  $T_2$  in the region of the windows. The exact dimensions are chosen to match the impedance based on the relative dielectric constant between the two regions. The technique of altering the width of the signal contacts in window regions is useful regardless of 25 why the window is formed in the connector and is not limited to windows formed to equalize delay. For example, some prior art connectors use windows over substantial portions of all the signal contacts to increase impedance of all the signal contacts.

30 FIG. 11A and 11B show an alternative embodiment that can be used to increase the effectiveness of a differential connector. FIG. 11A illustrates a portion of a backplane 600 to which a connector might be

attached. There are columns of holes 602 in backplane 600. The contact tails of the connector would be inserted into these holes to affix the connector to the backplane. One or more ground plane layers 604 are  
5 included within backplane 600. The ground plane layers are not deposited around the holes to avoid shorting out the connections made in the hole to leave exposed areas 606. However, in the prior art configuration shown in FIG. 11A, there is ground plane material deposited  
10 between the holes 602. FIG. 11B shows a backplane printed circuit board adapted for use with a differential connector. Ground plane layer 604 is deposited to leave an exposed area around the holes 602 that form a differential pair. In this way, there is no ground plane  
15 layer between the two holes of a differential pair. Consequently, the common mode coupling between the two conducting elements of the differential pair is improved.

Also, it should be appreciated that numbers and dimensions are given herein. Those numbers are for  
20 illustration only and are not to be construed as limitations on the invention. For example, connectors with 6 and 8 rows are illustrated. However, any number of rows could be conveniently made.

Also, it was described that shield plates could be  
25 used. Grounding members that are not plate shaped could also be used. The grounding members could be placed between pairs of conducting elements. In addition, the shields do not need to be planar. In particular, FIG. 3 and FIG. 4 illustrate a connector configuration in which  
30 there are spaces between differential pair. To increase the isolation between the differential pairs, tabs could be cut out of the shield plates and bent out of the plane of the plate to provide greater isolation between pairs.

It should also be recognized that the invention is illustrated by a right angle, press-fit, pin and socket connector. The invention is not useful simply in right angle applications. It could be used in stacking or  
5 mezzanine connectors. Nor is the invention limited to press-fit connectors. It could be used with surface mount or pressure mount connectors. Moreover, the invention is not limited to just pin and socket style connectors. Various contact configurations are known and  
10 the invention could be employed with other contact configurations.

What is claimed is:

1           1. An electrical connector module for conducting  
2 a pair of differential signals between electrical  
3 components, the connector module having opposing sides  
4 terminating along an edge, such module comprising:  
5           a pair of signal conductors, adapted for coupling  
6 to the pair of differential signals, disposed in the  
7 module, each one of the conductors having a corresponding  
8 contact portion, the contact portions of the conductors  
9 being laterally spaced along the edge of the module,  
10 surface portions of the pair of conductors passing from  
11 the contact portions through the module in substantially  
12 overlaying relationship along a direction extending  
13 through the sides of the module.

1           2. The connector module of claim 1, wherein the  
2 sides are parallel and the direction is perpendicular to  
3 the sides.

1           3. The connector module of claim 1, wherein the  
2 signal conductors of the pair have equal lengths.

1           4. The connector module of claim 1, wherein the  
2 signal conductors of the pair track along a majority of  
3 the length of the pair of signal conductors.

1           5. The connector module of claim 1, wherein the  
2 contact portions of the signal conductors are spaced  
3 equidistantly.

1           6. The connector module of claim 1, wherein at  
2 least some of the paired signal paths are connected to a  
3 set of differential signals.

1           7. The connector module of claim 1, further  
2 comprising a shield plate aligned adjacent to and spaced  
3 from the pair of signal conductors, the shield plate  
4 providing a common ground signal path.

1           8. The connector module of claim 7, further  
2 comprising an insulating member extending along a portion  
3 of the shield plate.

1           9. The connector module of claim 8, wherein the  
2 insulating member is a housing external to the shield  
3 plate and the pair of signal conductors.

1           10. An electrical connector module for  
2 transferring a plurality of differential signals between  
3 electrical components, the connector module comprising:  
4           a plurality of pairs of signal conductors, each  
5 pair having a first signal path and a second signal path,  
6 each signal path having a pair of contact portions, and  
7 an interim section extending between the contact  
8 portions;  
9           wherein for each pair of signal conductors a first  
10 distance between the interim sections is less than a  
11 second distance between the pair of signal conductors and  
12 any other pair of signal conductors of the plurality.

1           11. The connector module of claim 10, wherein the  
2 interim section of each first signal path is aligned in a  
3 first plane, and the interim section of each second  
4 signal path is aligned in a second plane spaced from the  
5 first plane.

1           12. The connector module of claim 10, wherein the  
2 interim section of each first signal path and the interim  
3 section of each second signal path are aligned in a  
4 plane.

1           13. The connector module of claim 10, wherein the  
2 interim sections of each pair of signal conductors have  
3 equal lengths.

1           14. The connector module of claim 10, wherein the  
2 interim sections of each pair of signal conductors track  
3 along a majority of the length of the interim sections.

1           15. The connector module of claim 10, wherein at  
2 least some of the paired signal paths are connected to a  
3 set of differential signals.

1           16. The connector module of claim 10, further  
2 comprising a shield plate spaced from the pairs of signal  
3 conductors, the shield plate providing a common ground  
4 signal path.

1           17. The connector module of claim 16, wherein the  
2 shield plate further comprises a main body and a tab, the  
3 tab extending from the main body and between at least two  
4 pairs of signal conductors.

1           18. The connector module of claim 16, wherein the  
2 shield plate further comprises a main body and a  
3 grounding contact portion extending from the main body.

1           19. The connector module of claim 18, wherein the  
2 grounding contact portion is adjacent to the contact

3 portions of the signal paths.

1           20. The connector module of claim 18, wherein the  
2 grounding contact portion extends between the contact  
3 portions.

1           21. The connector module of claim 18, wherein the  
2 grounding contact portion extends between adjacent  
3 contact portions of two signal paths.

1           22. The connector module of claim 16, wherein the  
2 shield plate further comprises a main body and a  
3 resilient tab, the resilient tab having ends connected to  
4 the main body, and the resilient tab extending from the  
5 main body.

1           23. The connector module of claim 22, wherein the  
2 resilient tab has a curved shape between the ends.

1           24. The connector module of claim 16, further  
2 comprising an insulating member extending along a portion  
3 of the shield plate.

1           25. The connector module of claim 24, wherein the  
2 insulating member is a housing external to the shield  
3 plate and the plurality of signal conductors.

1           26. An electrical connector module for  
2 transferring a plurality of differential signals between  
3 electrical components, the connector module comprising:  
4           a plurality of pairs of signal conductors, each  
5 pair having a first signal path and a second signal path,  
6 each signal path having a pair of contact portions, and

7 an interim section extending between the contact  
8 portions;  
9 wherein for each pair of signal conductors a first  
10 distance between the interim sections is less than a  
11 second distance between the pair of signal conductors and  
12 any other pair of signal conductors of the plurality; and  
13 wherein the interim section of each first signal  
14 path and the interim section of each second signal path  
15 of the pair are aligned in a single plane.

1 27. An electrical connector system for  
2 transferring a plurality of differential signals between  
3 electrical components, the connector system comprising:  
4 a connector module having;  
5 a plurality of pairs of signal conductors,  
6 each pair having a first signal path and a second signal  
7 path, each signal path having a pair of contact portions;  
8 wherein for each pair of signal conductors a  
9 first distance between the interim sections is less than  
10 a second distance between the pair of signal conductors  
11 and any other pair of signal conductors of the plurality;  
12 a shield plate spaced a distance from the  
13 pairs of signal conductors, the shield plate forming a  
14 common ground signal path;  
15 an insulating member extending along a  
16 portion of the shield plate;  
17 a printed circuit board having;  
18 a plurality of electrical contacts arranged  
19 in a row, a first portion of the electrical contacts  
20 providing a signal contact, a second portion of the  
21 electrical contacts providing a ground contact, the first  
22 portion of the electrical contacts attached to the  
23 contact portions, the second portion of the electrical

24 contacts attached to the shield plate;  
25                   an electrical signal routing channel adjacent  
26 to, and extending along, the row, the routing channel  
27 including a plurality of signal traces, each signal trace  
28 of the plurality being connected to a corresponding  
29 signal conductor.

1           28. The connector system of claim 27, wherein the  
2 interim section of each first signal path is aligned in a  
3 first plane, and the interim section of each second  
4 signal path is aligned in a second plane spaced from the  
5 first plane.

1           29. The connector module of claim 27, wherein the  
2 interim section of each first signal path and the interim  
3 section of each second signal path are aligned in a  
4 plane.

1           30. The connector system of claim 27, wherein the  
2 signal traces extend in a straight line along the row.

1           31. The connector system of claim 27, further  
2 comprising a plurality of connector modules.

1           32. The connector system of claim 31, wherein  
2 each connector module of the plurality is disposed  
3 directly adjacent to another connector module of the  
4 plurality.

1           33. An electrical connector assembly having an  
2 insulating housing and assembled thereto a plurality of  
3 electrical connector modules and electrically conductive  
4 shield plates therebetween, the assembly comprising;

5           a connector module having a plurality of signal  
6 paths, each signal path including a pair of contact  
7 portions and an interim portion therebetween, each of the  
8 connector modules having an electrically conductive  
9 shield plate mounted thereto, each connector module  
10 including first and second signal paths, the interim  
11 portions of said first signal paths being disposed in a  
12 first plane and the interim portions of said second  
13 signal paths being disposed in a second plane spaced from  
14 said first vertical plane and parallel therewith, the  
15 interim portions of said first signal contacts being  
16 proximate a first side of the module and spaced from an  
17 opposed second side thereof and the interim portions of  
18 said second signal paths being proximate said second side  
19 and spaced from said first side;

20           said contact portions of said first signal paths  
21 being staggered vertically with respect to said contact  
22 portions of said second contacts;

23           whereby, upon assembling the connector modules and  
24 the respective shield plates therebetween into the  
25 insulating housing, each interim portion of said first  
26 signal paths being spaced more closely to a corresponding  
27 interim portion of one of said second signal paths than  
28 to any other interim portion of either said first or  
29 second signal paths, each interim portion of said second  
30 signal paths being spaced more closely to a corresponding  
31 interim portion of one of said first signal paths than to  
32 any other interim portion of either said first or second  
33 signal paths, thereby assuring primary coupling between  
34 each corresponding first and second signal paths rather  
35 than to an adjacent said signal contact pair.

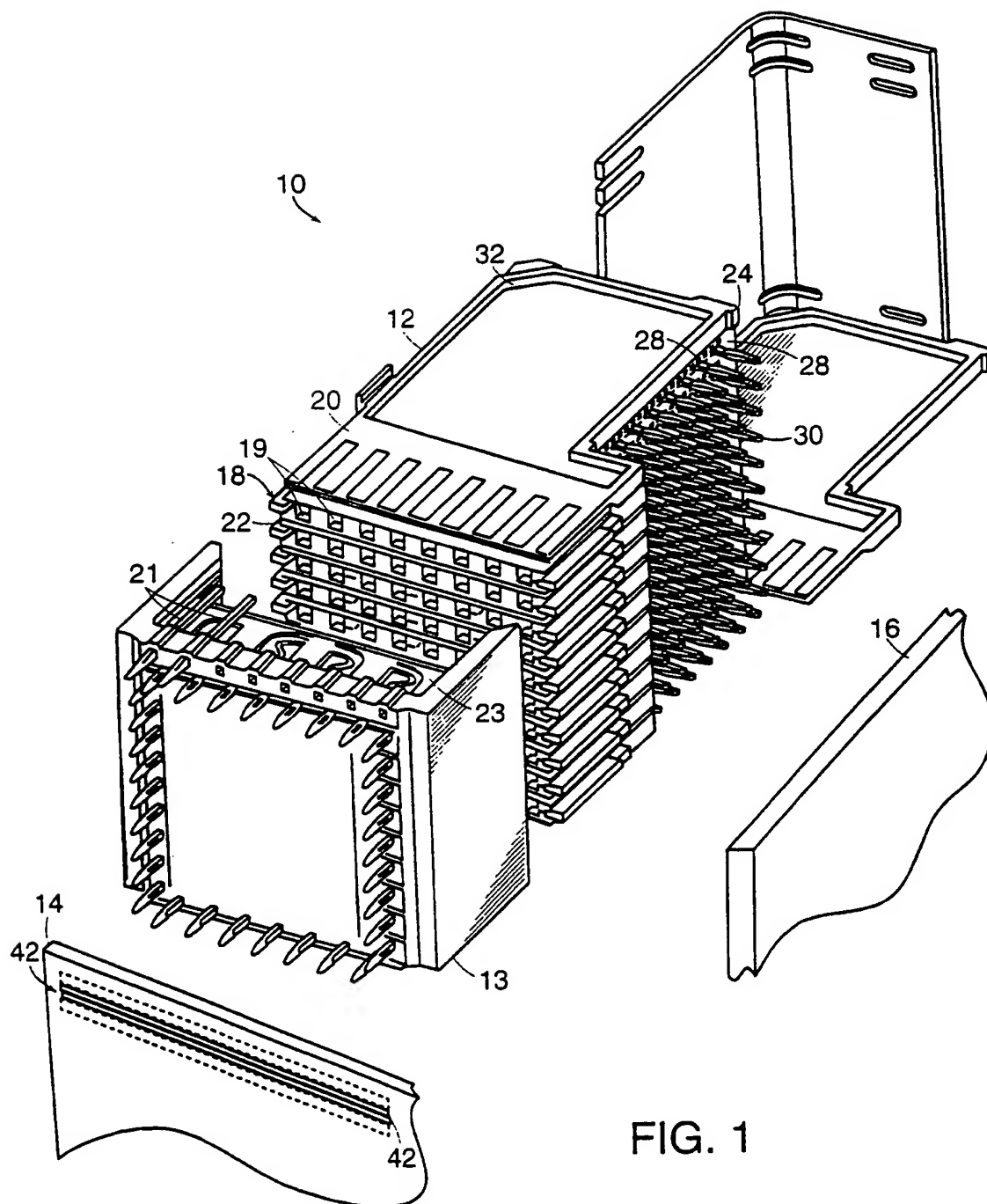


FIG. 1

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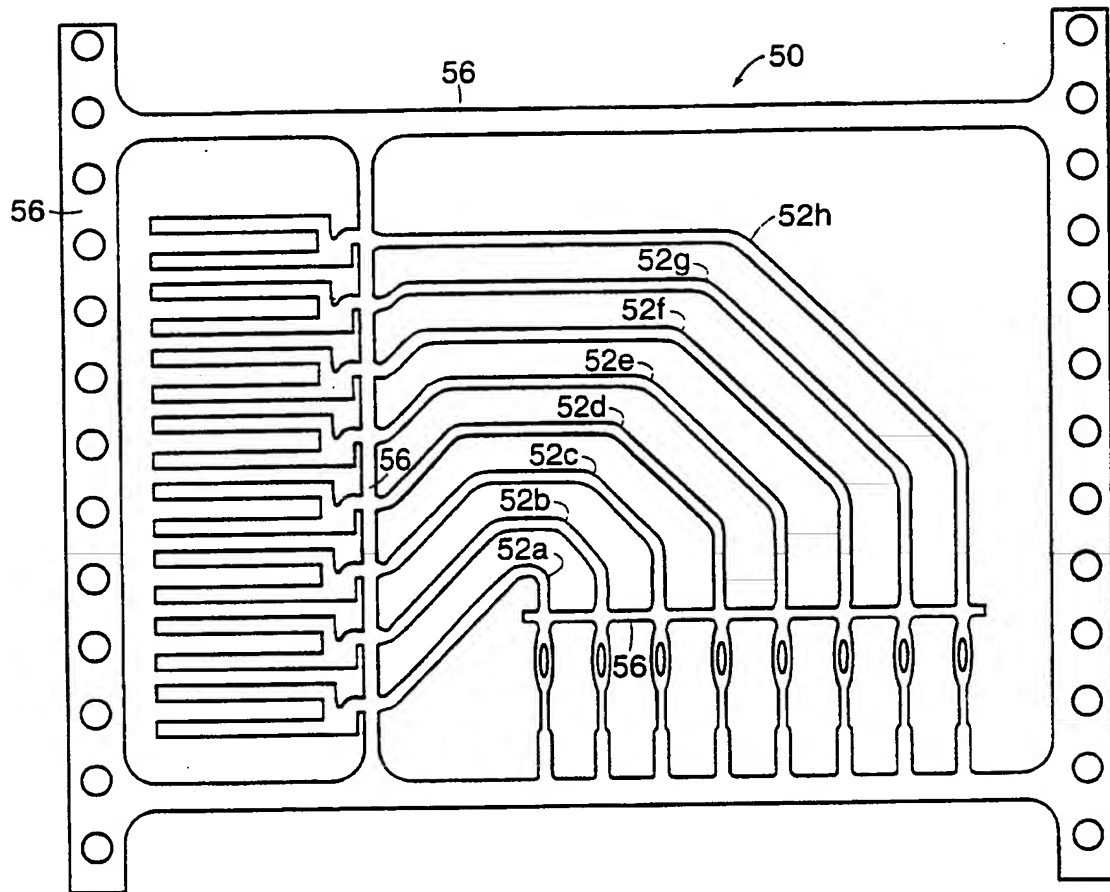


FIG. 2  
(PRIOR ART)

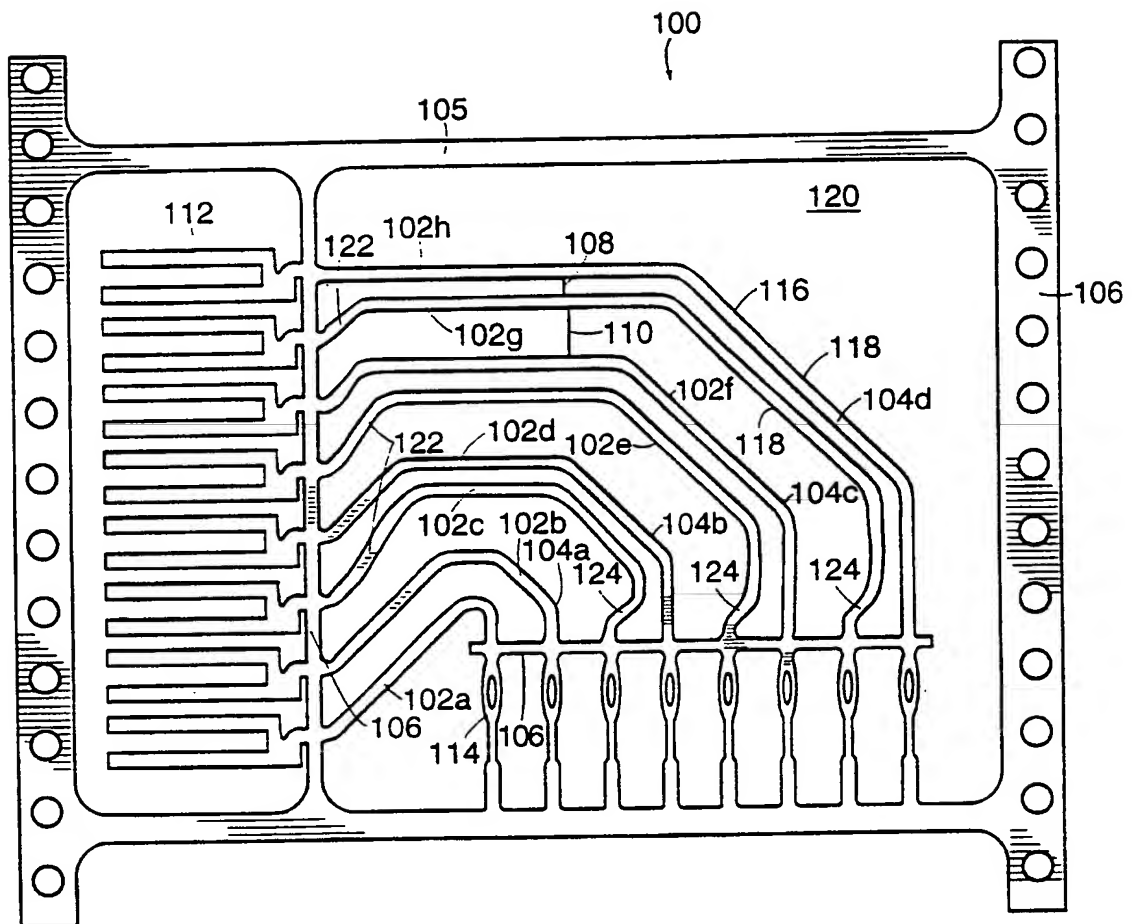


FIG. 3

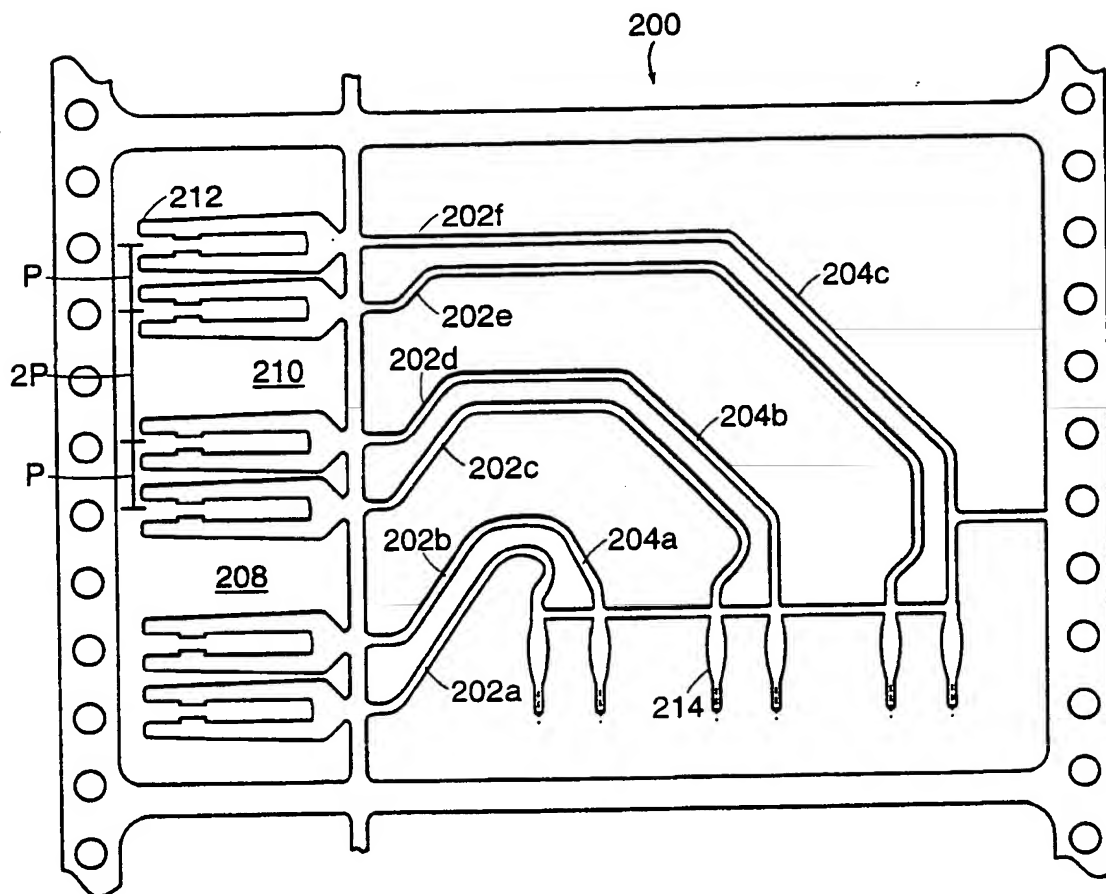


FIG. 4

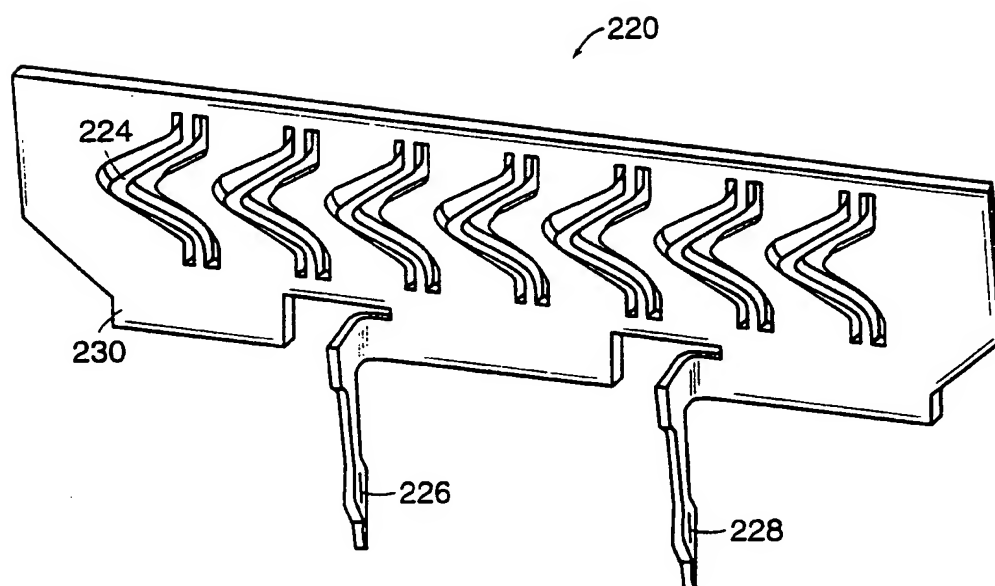
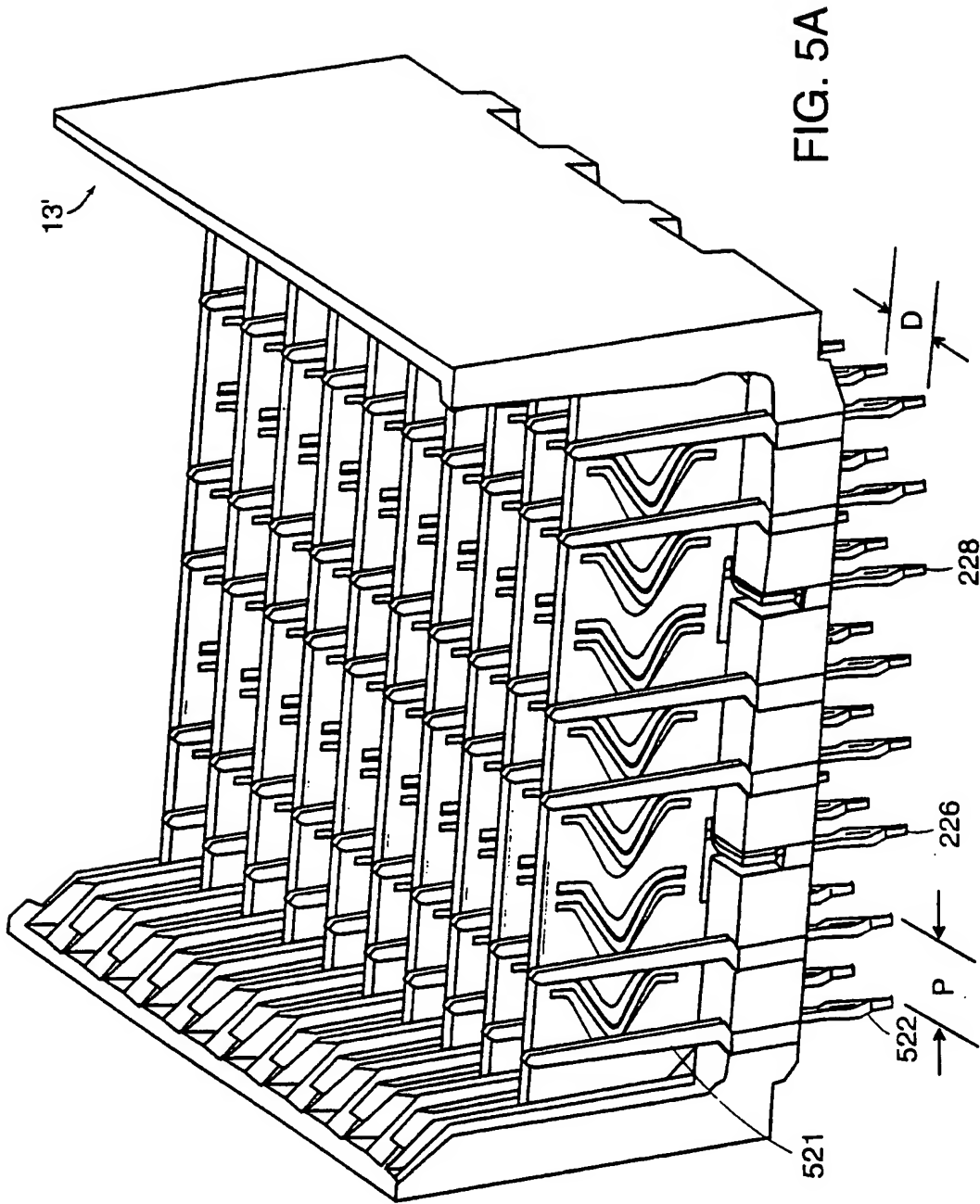


FIG. 5



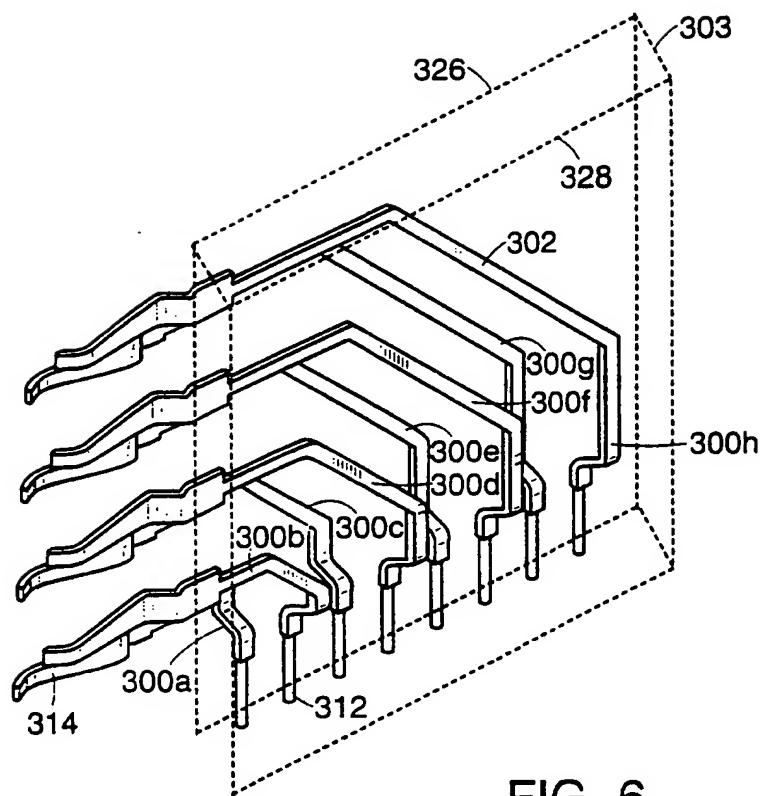
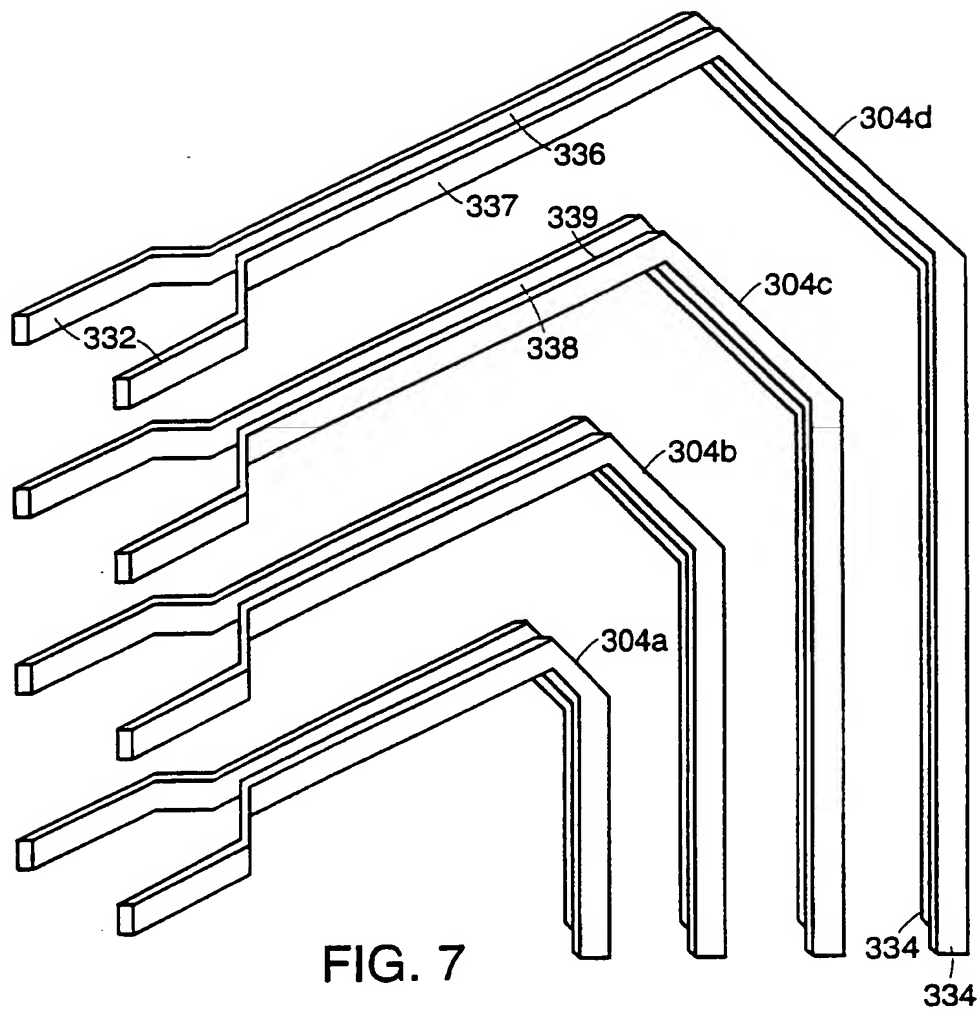


FIG. 6  
(PRIOR ART)



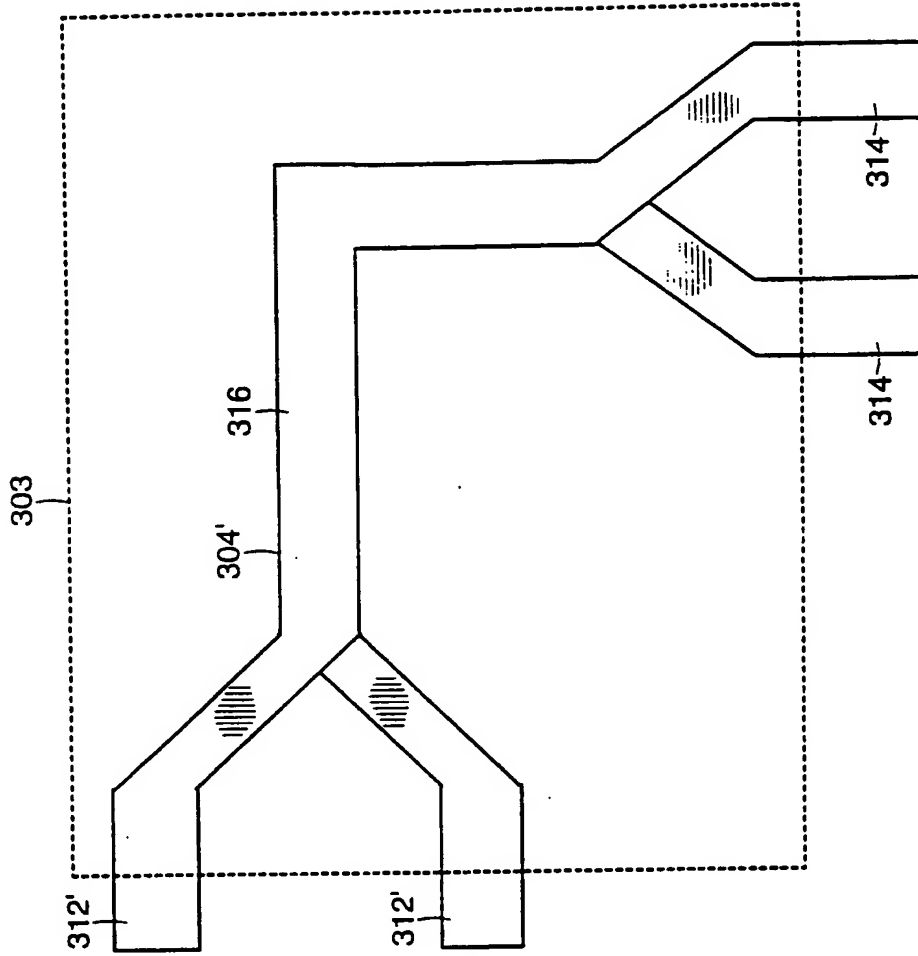


FIG. 9

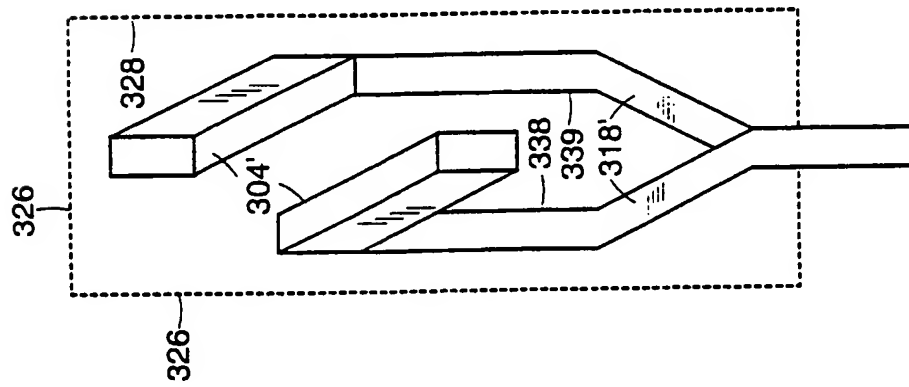


FIG. 8

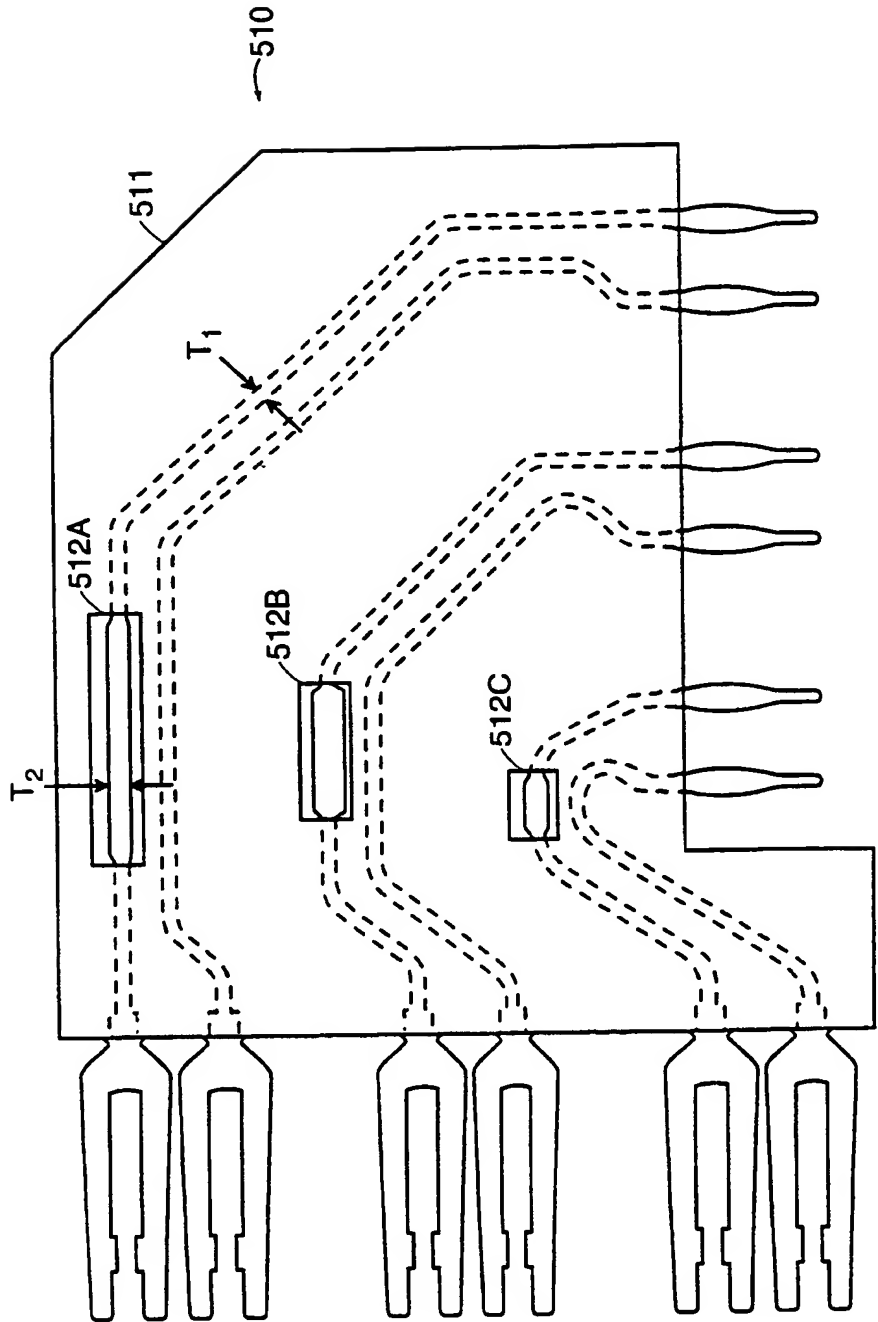


FIG. 10

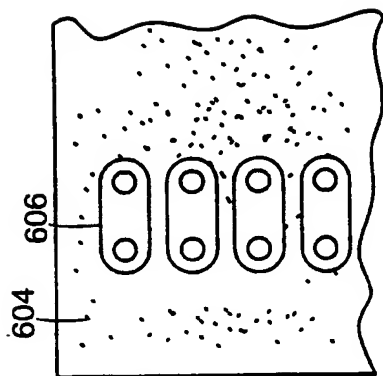


FIG. 11B

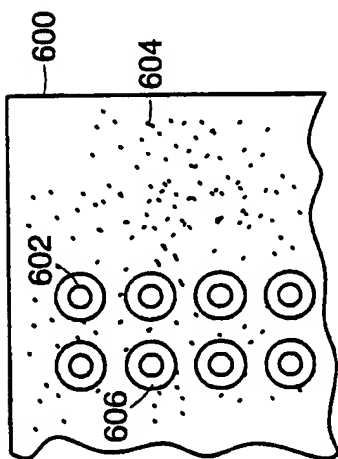


FIG. 11A  
(PRIOR ART)

## INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 99/27868

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H01R12/16 H01R12/18 H01R24/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 795 191 A (PREPUTNICK GEORGE ET AL) 18 August 1998 (1998-08-18) abstract; figures 1-4 ---	1,10,26, 27,33
A	US 5 496 183 A (SOES LUCAS ET AL) 5 March 1996 (1996-03-05) column 2, line 51 -column 3, line 15; figures 1,12 ---	1-9
A	US 5 429 520 A (MORLION DANNY ET AL) 4 July 1995 (1995-07-04) cited in the application abstract; figures 1,4 ---	1-9
A	US 5 605 476 A (MCNAMARA DAVID M ET AL) 25 February 1997 (1997-02-25) --- -/--	



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

## \* Special categories of cited documents :

\*A\* document defining the general state of the art which is not considered to be of particular relevance

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\*O\* document referring to an oral disclosure, use, exhibition or other means

\*P\* document published prior to the international filing date but later than the priority date claimed

\*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

\*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

\*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

\*&amp;\* document member of the same patent family

Date of the actual completion of the international search

24 July 2000

Date of mailing of the international search report

03.08.00

Name and mailing address of the ISA

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## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 99/27868

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category <sup>2</sup>	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
5	A US 5 860 816 A (PROVENCHER DANIEL B ET AL) 19 January 1999 (1999-01-19) column 2, line 31 -column 3, line 5; figures 1,4 ---	10,26, 27,33
4	A EP 0 422 785 A (AMP INC) 17 April 1991 (1991-04-17) abstract; figures 5,6,11,12 ---	10,26, 27,33
6	A EP 0 622 871 A (WHITAKER CORP) 2 November 1994 (1994-11-02) abstract; figure 1 ---	10,26, 27,33
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# INTERNATIONAL SEARCH REPORT

national application No.  
PCT/US 99/27868

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-9

An electrical connector module comprising a pair of signal conductors extending within the module in overlaying relationship along a direction extending through the sides of the module.

2. Claims: 10-25, 26, 27-32, 33

Claims 10-25:

An electrical connector module comprising a plurality of pairs of signal conductors wherein for each pair of conductors a first distance between the interim sections extending between the contact portions of the conductors is less than a second distance between the pair of signal conductors and any other pair of signal conductors of the plurality.

Claim 26:

An electrical connector module having the features of the module as defined in claim 25 with the additional feature that the interim section of each first signal path and the interim section of each second signal path of the pair of signal conductors are aligned in a single plane.

Claims 27-32:

An electrical connector system comprising a module, a shield plate, an insulating member, and a printed circuit board

Claim 33:

An electrical connector assembly having an insulating housing and a plurality of modules and electrically conductive shield plates therebetween.

## INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 99/27868

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
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Information on patent family members

International Application No

PCT/US 99/27868

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